JOURNAL OF THE TENNESSEE ACADEMY OF SCIENCE 84(3):47–51 JULY 2009

STREAM QUALITY ASSESSMENT ON MILITARY TRAINING GROUNDS NEAR WAVERLY, TENNESSEE*

MARK D. FARR, MARK D. ANTWINE, AND LAURA P. LECHER

Aquatic Ecology and Invasive Species Branch, U.S. Army Corps of Engineers, Engineer Research and Development Center, 3909 Halls Ferry Road, Vicksburg, MS 39180 (MDF, MDA)
Environmental Office, Tennessee Army National Guard, 3041 Sidco Drive, Nashville, TN 37204 (LPL)

ABSTRACT—Rapid bioassessment protocols were used during February 2005 to characterize stream quality in a reach of Trace Creek located within the Tennessee Army National Guard Volunteer Training Site—Gorman Quarry near Waverly, Tennessee. The purpose of the study was to characterize stream quality and provide background information for a more comprehensive biological inventory of the training site. Field, laboratory, and analytical methods closely followed those developed for stream assessments by the Tennessee Department of Environment and Conservation. Data describing physical habitat conditions, water quality parameters, and benthic macroinvertebrate assemblages were collected from among 9 sites along Trace Creek. Trace Creek data were compared with similar data from other streams in the Highland Rim Bioregion of the state. These comparisons indicated that Trace Creek contained high quality habitat and an abundance of environmentally "sensitive" benthic macroinvertebrate taxa. Data analyses indicated that Trace Creek would be classified as "non-impaired and fully supporting of designated water usages" according to the Tennessee Department of Environment and Conservation guidelines.

The 155th Engineering Asphalt and Rock Crushing Company of the Tennessee Army National Guard trained with heavy rock-moving machinery and vehicles from 2002–2007 at the Volunteer Training Site—Gorman Quarry (VTS-G) near Waverly, Tennessee. Information describing ecological conditions within a segment of Trace Creek flowing through the installation was gathered as part of an overall biological inventory for the site. Estimates of stream habitat quality, biodiversity, presence of threatened and endangered species, and organism-habitat relationships can often be determined with a modest, carefully planned, sampling effort. Information obtained from such studies can be used by resource managers to evaluate and minimize the potential impacts of training exercises or land-management techniques on natural resources.

Benthic macroinvertebrates are the focus of many studies designed to evaluate and monitor stream quality (Barbour et al., 1999) at small spatial (local upstream influence) and temporal scales (one to several years). Information describing distribution, habitat associations, and life-history patterns of many taxa is available for many regions of the country (Merritt and Cummings, 1996; Thorp and Covich, 2001). For this reason, many states have adopted specific methods for sampling benthic macroinvertebrates as part of their statewide stream quality assessment programs (Maryland Department of Natural Resources, 2003; West Virginia Department of Environmental Protection, 2003).

The Tennessee Department of Environment and Conservation (TDEC) has published a guide for conducting macroinvertebrate surveys in Tennessee streams (TDEC, 2003; Arnwine and Denton, 2001). Development of standard field methods and analytical techniques strengthens and simplifies the process of assessing baseline stream conditions. For example, Smith (1994) used these methods to characterize water quality downstream of our project area, at a site where effluent from a sewage treatment plant entered Trace Creek, as "not fully supporting of its designated water usages" (degraded).

The primary objective of the present study was to apply the TDEC stream assessment protocol to Trace Creek at several sites within the VTS-G. This paper contains a brief discussion of our results and addresses the benefits of using standard stream assessment methods as part of a larger overall natural resources management plan for military lands.

METHODS AND MATERIALS

Study Area—Trace Creek is a third-order stream that originates 11.3 km upstream of the VTS-G. An approximately 1,430 m reach of Trace Creek occurs within the training site (Fig. 1). Trace Creek is located within the Western Highland Rim bioregion (Arnwine and Denton, 2001) of Tennessee. Streams in this bioregion are typically clear and have moderate gradients with beds comprised of gravel, sand, and occasionally bedrock. The Trace Creek watershed is dominated by cattle pasture, hay fields, and forest (Arnwine and Denton, 2001). Overland erosion and sedimentation as well as nonpoint inputs of nutrients and other pollutants associated with local agriculture practices are potential stressors to Trace Creek within the VTS-G boundaries.

We used standard TDEC protocols for invertebrate sampling, habitat assessment, and data analysis (TDEC, 2003). We conducted physical habitat assessments, measured water quality parameters, and collected benthic macroinvertebrate samples on 8–9 February 2005. Data describing physical

*Processed by M. Gore Ervin, the previous Managing Editor of the journal.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JUL 2009**	2. REPORT TYPE	3. DATES COVERED **00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE **Stream Quality Assessment on Military Training Grounds Near Waverly, Tennessee**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Ai?ua lie Ecology and Invasive Species Branch. U.S. Army Corps of Engineers,Engineer Research and Development Center. 3909 Halls Ferry Road,Vicksburg,MS,39180**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

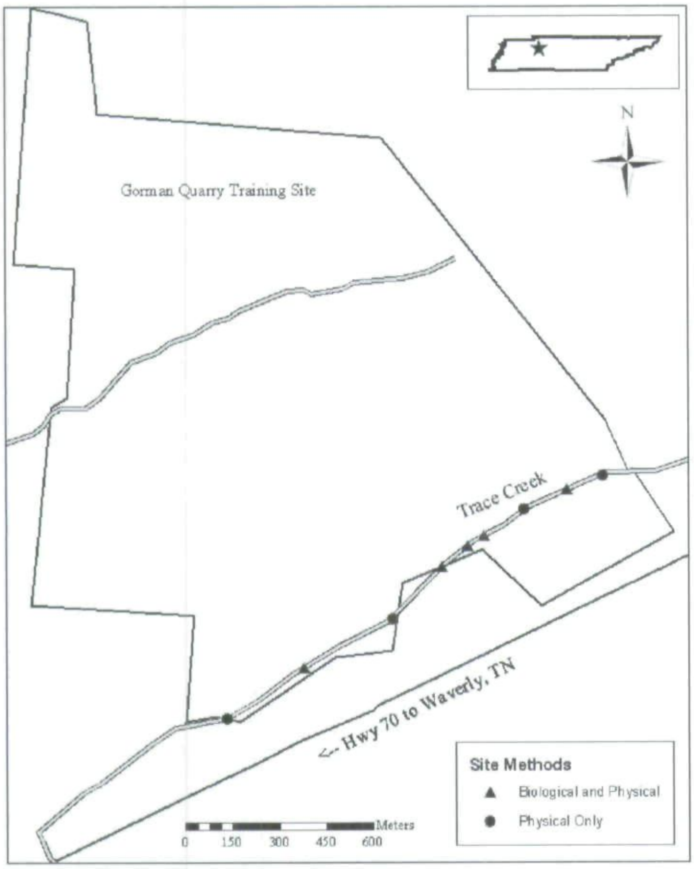

FIG. 1. Sampling sites for a benthic macroinvertebrate stream assessment survey at the Tennessee Army National Guard Volunteer Training Site—Gorman Quarry near Waverly, Tennessee, February 2005.

habitat conditions were collected at nine stream sites (Fig. 1, Table 1). Water quality measurements and benthic macroinvertebrate samples were collected at five stream sites.

Water Quality Parameters—Data describing pH, conductivity, temperature, dissolved oxygen concentration, and turbidity were measured using a Hydrolab Quanta and a Hach 2100P Turbidimeter.

Physical Habitat Assessments—Experienced field personnel evaluated physical habitat quality using the recommended "high-gradient stream survey form" (TDEC, 2003). Accordingly, we used 10 metrics to describe physical habitat status of the stream. Calculated values for each metric were assigned a score from 0 (lowest quality) to 20 (highest quality). Descriptions of each follow:

1) Epifaunal substrate—How much cover/surface area is provided by the substratum (cobble, large rocks, logs and woody debris, and undercut banks) as refugia for macroinvertebrates and fish.
2) Embeddedness—The depth that rocks or logs are embedded in sand, silt, or mud can be correlated with erosion within a watershed and subsequent sedimentation within a stream; low embeddedness indicates better habitat conditions.
3) Velocity and depth—Stream reaches with all four velocity/depth regimes were given the highest scores, whereas reaches with only one or two of these habitat regimes were given lower scores.
4) Sediment deposition—Excessive deposition occurring throughout a reach can result in the formation of point bars or the filling of pools and runs with sand, silt, or mud; heavy levels of deposition indicates poor habitat quality.
5) Channel flow status—The amount of the stream channel covered by water. A low percentage of substrate covered by water represents limited habitat availability to in-stream organisms.
6) Channel alteration—The presence of unnatural stream conditions, such as riprap, bridges, or sections of channelized (straightened) stream can indicate low habitat quality.
7) Frequency of riffles—The presence of typical riffle/pool habitats at a site. Riffles occurring less than 7 stream widths from one another are considered optimal. For example, if a stream is 5 m wide then riffles should be no more than 35 m from the end of one to the beginning of the next to be considered optimal.
8) Bank stability—The amount of erosion or potential for erosion in a reach. Unprotected, steep banks with exposed soils receive the lowest scores, whereas gently sloping banks covered with rooted vegetation are given higher scores.
9) Bank vegetative protection—The amount of coverage/protection from erosion afforded stream banks by plants. Plants are also involved in nutrient uptake and provide allochthonous organic material for detritivores.
10) Riparian vegetative zone width—The width of mature vegetation within 18 m of the stream bank. The presence of roads, agriculture, and other human developments are assumed to decrease stream quality (increasing run-off, nutrient loads, and sedimentation rates).

For each metric, scores from 16–20 are considered optimal, whereas scores of 1–5, 6–10, and 11–15 are considered poor, marginal, and sub-optimal, respectively. The greatest possible score for a stream reach was 200. To assess the relative condition of Trace Creek, we referred to standard scores from other reference streams in the region (TDEC, 2003). Scores in the top quartile (greatest 25%) were considered representative of optimal stream condition.

Biological Sampling—Benthic macroinvertebrate samples were collected in accordance with TDEC (2003) protocols using semi-quantitative kick (SQKICK) samples. At each stream site, a 1 m^2 net (500 μm mesh) was positioned near the downstream edge of a riffle. Substrate immediately upstream was disturbed for 20–30 seconds to dislodge and wash organisms into the net. The net was taken to shore, where all contents were washed into a sample container. Forceps were used to remove organisms clinging to the net. The process was repeated a few meters upstream of where the first sample was collected. After debris from both kicks was placed into the sample container, a weak ≤10%) formaldehyde solution was used to preserve contents.

Laboratory Analysis—Sample material from each site was spread evenly in a shallow tray and divided into 30 equivalent subsamples. Randomly selected subsamples were processed until 200 (± 20) organisms were removed. These organisms were identified to genus or lowest practical taxon level (Merritt and Cummins, 1996; Thorp and Covich, 2001).

TABLE 1. Habitat assessment values with 25th percentile ranks (target value for "non-impaired" classification) of reference streams.

Site	Epifaunal Substrate	Embeddedness	Velocity/ Depth	Sediment Deposition	Channel Flow Status	Channel Alteration	Freq. of Riffles	Bank Stability	Vegetative Protection	Riparian Veg Width	Total
1	19	19	18	18	15	20	19	15	13	19	175
2	15	18	15	17	16	20	17	14	15	12	159
3	18	18	19	18	15	19	18	16	14	11	166
4	18	18	19	16	18	15	18	10	4	3	139
5	19	18	18	16	18	20	18	13	12	15	167
6	19	18	17	18	15	20	19	15	11	18	170
7	16	18	19	19	17	20	20	13	8	20	170
8	16	15	17	17	15	20	18	13	6	19	156
9	18	19	16	18	17	20	17	14	12	19	170
Mean	17.6	17.9	17.6	17.4	16.2	19.3	18.2	13.7	10.6	15.1	163.6
25%	12	13	12	11	11	14	13	12	14	12	124

Data Analysis—We applied TDEC methods for assessing stream quality relative to other streams within the same region of the state. Macroinvertebrate data were first analyzed and "scored" using seven metrics (Arnwine and Denton, 2001):

1) Ephemeroptera, Plecoptera, and Trichoptera taxa (EPT)—These taxa are typically less tolerant of perturbation than many other taxa.
2) Taxa richness (TR)—The total number of taxa found at a site. Low taxa richness can be indicative of habitat perturbation.
3) Percent Oligochaeta and Chironomidae (% OC)—A high percentage of these taxa can indicate low dissolved oxygen concentration (DO), elevated sedimentation rates, or high levels of suspended solids.
4) Percent EPT (% EPT)—This metric is often positively correlated with overall stream condition.
5) North Carolina Biotic Index (NCBI)—This metric uses environmental tolerance values indicative of each taxon's sensitivity to environmental perturbation. For example, *Dicrotendipes* (Diptera: Chironomidae) has a tolerance value of 8.0, which indicates that organisms in this genera are less susceptible to environmental change or degraded habitat conditions. *Isoperla* (Plecoptera: Perlodidae) has a tolerance value of 1.5, which suggests this taxa group is more susceptible to environmental perturbation. Tolerance values (TDEC, 2003) for each organism are summed and divided by the total number of organisms to calculate an average tolerance score for each sample or site.
6) Percent dominance (% DOM)—The relative abundance of the most common taxa at a site. High percent dominance is often associated with degraded or low habitat diversity.
7) Percent clingers (% CLG)—An abundance measure of organisms that are adapted to stable, hard substrates. Habitat stability is often considered an important component of good stream quality.

Calculated values for each metric were equalized by assigning scores of 0–6 (habitat conditions of a test stream are among the worst (0) or best (6) relative to other streams in the same region of the state) using TDEC guidelines. Equalized scores for these 7 metrics were summed to calculate a "bioregion score." The maximum possible bioregion score was 42; scores of 32 or higher (top quartile, or 25%) indicate non-impaired stream conditions.Waypoints were collected in the field using a Garmin Geographic Positioning System (Model Map 76). ArcGIS 8 software was used to create maps and measure stream distances.

RESULTS AND DISCUSSION

Physical habitat was evaluated at all nine sites along Trace Creek within the VTS-G boundaries (Fig. 1). Much of the reach was bordered by immature forest; estimates of canopy cover averaged only 7.8%. Sediment deposits were slight and consisted mainly of sand. Measured water depths ranged from 4–80 cm with a few large pools exceeding 150 cm. Trace Creek average stream width was 10 m. Substratum ranged from boulder to sand, with gravel (37.7%) and cobble (34.9%) being dominant. Habitat assessment scores among the nine sites ranged from 139–175 (Table 1). The average site score of 163.6 exceeded the Habitat Assessment Guidelines (TDEC, 2003) minimum target score (123) for "non-impaired" streams.

Water chemistry measurements fell within the following value ranges: pH (6.06–6.29), conductivity (127–171 μS), temperature (10.7–11.6°C), dissolved oxygen (5.33–5.76 mg/L), and turbidity (2.60–7.35 NTU). These results do not indicate any obvious problems in water quality at sampling sites within Trace Creek.

The macroinvertebrate community reflected both good water quality and physical habitat conditions. Thirty-eight benthic invertebrate taxa were identified from samples collected among the five Trace Creek sites (Appendix 1). No threatened or endangered stream macroinvertebrates were encountered. The most common taxon was *Isoperla* (Plecoptera: Perlodidae), which comprised 26.4% of the fauna. Plecoptera larvae are usually associated with clean, clear streams and have specific habitat and water quality requirements (Merritt and Cummins, 1996). Other common taxa in the Trace Creek assemblage included *Acentrella*

TABLE 2. Calculated metric values for sites located along Trace Creek.

Site ID	EPT[a]	TR[b]	%OC[c]	%EPT[d]	NCBI[e]	%DOM[f]	%CLG[g]
2	7	16	24.5	71.8	3.4	41.0	58.5
4	9	28	21.4	72.8	3.1	44.5	62.4
5	8	18	13.2	68.6	3.6	24.0	40.2
7	9	20	21.7	61.4	4.0	25.1	16.4
9	7	21	28.7	55.7	4.0	19.3	43.2
Mean	8.0	21.6	21.9	66.1	3.6	30.8	44.2

[a] Ephemeroptera, Plecoptera, and Trichoptera taxa.
[b] Taxa richness.
[c] Percent Oligochaeta and Chironomidae.
[d] Percent Ephemeroptera, Plecoptera, and Trichoptera taxa.
[e] Mean North Carolina Biological Index score.
[f] Percent dominance.
[g] Percent clingers.

(Ephemeroptera: Baetidae—16.8%), *Cricotopus/Orthocladius* (Diptera: Chironomidae—7.5%), and immature Heptageniidae (Ephemeroptera—7.0%). Ephemeroptera are widely distributed in lotic and lentic systems, although second- and third-order streams with rocky bottoms often have the greatest diversity (Merritt and Cummins, 1996). The remaining 34 genera had relative abundances less than 6.5%. *Isoperla* (Plecoptera: Perlodidae) was dominant at all stream sites except TC4, where *Acentrella* (Ephemeroptera: Baetidae) had the highest relative abundance of 25.1%. The prevalence of environmentally "sensitive" stonefly and mayfly taxa in Trace Creek samples provided an initial indication of good stream quality.

Previous land management and training practices have not resulted in poor stream quality in the VTS-G portion of Trace Creek. Biometric values (Table 2) for Trace Creek translated into bioregion-based scores of 32–36 (mean = 33.6; Table 3). Streams in the Western Highland Rim Bioregion with scores greater than 31 are considered "non-impaired and fully supporting of designated water usages" (TDEC, 2003).

Natural resource management on military lands often requires development of an Integrated Natural Resource Management Plan or basic environmental monitoring plans. Primary objectives should include maintenance of high stream quality within potentially affected watersheds. Implementation of best management practices (BMPs) can minimize potential impacts of training exercises and resource management activities on aquatic habitats. Also, a standard stream bioassessment program can be used to monitor and identify ecological changes in stream quality. Management plans that combine these two practices offer both a proactive effort to minimize problems before they occur (BMPs) as well as a "system check" measure (RBPs monitoring) to recognize a problem before, or relatively soon after, it occurs.

ACKNOWLEDGMENTS

This project was funded by the Tennessee Army National Guard Environmental Office. B. Payne, J. Killgore, and J. Hoover reviewed an early version of the manuscript.

LITERATURE CITED

ARNWINE, D. H., AND G. M. DENTON. 2001. Development of regionally based numeric interpretations of Tennessee's biological integrity criterion. Tenn. Dept. Environ. and Cons., Div. Water Poll. and Control. Nashville, Tennessee.

BARBOUR, M. T., J. GERRITSEN, B. D. SNYDER, AND J. B. STRIBLING. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, 2nd ed. EPA 841-B-99-002.

MARYLAND DEPARTMENT OF NATURAL RESOURCES. 2003. River and streams, synopsis of MBSS design and sampling methods, Available via the INTERNET (*http://www.dnr.state.md.us/streams/ mbss/synopsis.html*).

MERRITT, R. W., AND K. W. CUMMINS. 1996. An introduction to the aquatic insects of North America, 3rd ed. Kendall/Hunt Pub. Co., Dubuque, Iowa.

TABLE 3. Bioregion scores for Trace Creek benthic macroinvertebrate index.

Site ID	EPT[a]	TR[b]	%OC[c]	%EPT[d]	NCBI[e]	%DOM[f]	%CLG[g]	Total
2	2	2	6	6	6	4	6	32
4	4	4	6	6	6	4	6	36
5	4	2	6	6	6	6	4	34
7	4	4	6	6	6	6	0	32
9	2	4	6	6	6	6	4	34
Mean	3.2	3.2	6.0	6.0	6.0	5.2	4.0	33.6

[a] Ephemeroptera, Plecoptera, and Trichoptera taxa.
[b] Taxa richness.
[c] Percent Oligochaeta and Chironomidae.
[d] Percent Ephemeroptera, Plecoptera, and Trichoptera taxa.
[e] Mean North Carolina Biological Index score.
[f] Percent dominance.
[g] Percent clingers.

SMITH, J. R. 1994. Trace Creek intensive survey, receiving waters for Waverly, STP, Humphreys County, Tennessee. Tenn. Dept. Water Poll. Control. Nashville, Tennessee.

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION – DIVISION OF WATER POLLUTION CONTROL. 2003. Quality systems standard operating procedures for macroinvertebrate stream surveys. Nashville, Tennessee.

THORP, J. H., AND A. P. COVICH. 2001. Ecology and classification of North American freshwater invertebrates, 2nd ed Academic Press, San Diego, California.

WEST VIRGINIA DEPARTMENT OF ENVIRONMENTAL PROTECTION. 2003. West Virginia save our streams: advanced stream assessment protocols West Virginia Department of Environmental Protection, Charleston, West Virginia.

APPENDIX A

Benthic macroinvertebrate taxa collected in Trace Creek at the Tennessee Army National Guard Volunteer Training Site, near Waverly, Tennessee, February 2005. Tolerance values (TV) as well as designations of intolerant (IT) and clinger (CLG) taxa are indicated.

Order	Family	Genus	Total	TV	IT/CLG
Amphipoda	Crangonyctidae	*Crangonyx*	3	7.87	
Coleoptera	Elmidae	*Optioservus*	1	2.36	IT, CLG
Diptera	Chironomidae		17	5.12	
Diptera	Chironomidae	*Corynoneura*	5	6.01	
Diptera	Chironomidae	*Cricotopus/Orthocladius*	72	4.86	CLG
Diptera	Chironomidae	*Eukiefferiella*	1	3.43	
Diptera	Chironomidae	*Polypedilum*	6	5.69	
Diptera	Chironomidae	*Tanytarsus*	10	6.76	
Diptera	Chironomidae	*Thienemanniella*	28	5.86	
Diptera	Chironomidae	*Thienemannimyia*	6	6.2	
Diptera	Chironomidae	*Tvetenia*	1	3.65	
Diptera	Chironomidae	*Zavrelia*	11	5.3	
Diptera	Simuliidae	*Simulium*	11	4	CLG
Diptera	Simuliidae	*Prosimulium*	2	4.01	CLG
Diptera	Tipulidae	*Dicranota*	2	0	IT
Ephemeroptera	Baetidae	*Acentrella*	162	3.6	
Ephemeroptera	Caenidae	*Caenis*	4	7.41	
Ephemeroptera	Heptageniidae		67	4	CLG
Ephemeroptera	Heptageniidae	*Leucrocuta*	1	2.4	IT, CLG
Ephemeroptera	Heptageniidae	*Maccaffertium*	5	3	
Ephemeroptera	Isonychiidae	*Isonychia*	37	3.45	
Ephemeroptera	Leptophlebiidae		1	1.8	IT
Hydracarina			1	5.53	
Isopoda	Asellidae	*Lirceus*	59	7.85	
Oligochaeta	Lumbriculidae		2	7.3	
Oligochaeta	Naididae		51	8.94	
Plecoptera	Capniidae		44	0.9	IT
Plecoptera	Chloroperlidae		1	0.7	IT
Plecoptera	Chloroperlidae	*Haploperla*	5	0.98	IT, CLG
Plecoptera	Chloroperlidae	*Sweltsa*	2	0	IT, CLG
Plecoptera	Leuctridae		10	0.2	IT
Plecoptera	Leuctridae	*Leuctra*	1	0.67	IT, CLG
Plecoptera	Nemouridae		38	1.2	
Plecoptera	Nemouridae	*Amphinemura*	1	3.33	
Plecoptera	Perlidae	*Clioperla*	1	4.72	
Plecoptera	Perlodidae	*Isoperla*	254	1.5	IT, CLG
Trichopetera	Rhyacophilidae	*Rhyacophila*	1	0.73	IT, CLG
Turbellaria			40	4	
		Total	964		
		# spp.	38		
		Mean tolerance score	3.66		